TITLE OF THE INVENTION

COMPOSITIONS FOR PRODUCING ARCHITECTURAL CEMENTITIOUS STRUCTURES HAVING DECORATIVE AGGREGATE-CONTAINING CEMENTITIOUS SURFACES AND PROCESSES THEREFOR

CROSS-REFERENCE TO RELATED APPLICATIONS

This application is a Continuation-in-Part of Serial No. 10/058,932, filed January 28, 2002, which claims the benefit of the priority of U.S. Provisional Application Serial No. 60/270,732, filed February 22, 2001. Serial No. 10/058,932 is hereby incorporated herein by reference in its entirety.

BACKGROUND OF THE INVENTION

Methods to incorporate varicolored fragments of material in wall surfaces have been known. For example, U.S. Patent No. 772,476 discloses a method of veneering artificial stone by depositing a layer of cement on the face of a block, sprinkling granular material thereon, tamping the granular material and smoothing the surface by rubbing or grinding the exposed granules.

U.S. Patent No. 1,361,763 discloses a method of mixing foreign particle with a conventional plastic mixture, which is then applied directly to the surface to be covered.

U.S. Patent No. 4,496,504 discloses a method of exposing aggregate in poured concrete panels by pouring wet concrete having a coarse aggregate content into a casting bed, lifting coarse aggregate to the surface with a rotating aggregate lifter and

depositing a high concentration of the coarse aggregate in front of a screed roller, and compacting.

U.S. Patent No. 5,339,589 produces an aggregate floor by applying a layer of a flexible compound to a concrete slab, applying fiber glass mesh to the flexible compound, applying dry aggregate to the mesh and compacting with a vibrating roller, then applying thereto a compacted composite cement, water and sand in the form of a viscous solution, and then compacting with a roller to force out excess cement and trapped air.

U.S. Patent No. 5,794,401 discloses a method of resurfacing existing floors or substrates by cleaning the surface of the substrate and applying a seed material mixed with a cementitious self-leveling topping, then curing, then grinding the exposed cured surface, and then sealing.

U.S. Patent Nos. 6,016,635 and 6,033,146 disclose methods for surface seeding or broadcasting particulate over the surfaces of poured concrete mixes while the top surfaces are still plastic.

U.S. Patent No. 1,486,208 discloses a method of coloring white transparent crushed marble or silica for making colored surfaces by coloring such materials which after drying are then molded into the required form with a cement base.

U.S. Patent No. 2,277,203 discloses a method of producing a granolithic floor or road surface. A diluted liquid hardener is applied to a concrete foundation layer prior to its complete drying and hardening thereof. Then a dry granolithic topping mixture of cement and granite or like chips without other ingredients is

spread over the surface of the foundation layer by hand or otherwise. The topping mixture is tamped to unite with and penetrate the foundation layer which is said to produce a monolithic construction.

U.S. Patent No. 4,198,472 discloses a method of forming an exposed aggregate surface coating on a swimming pool by pumping a mix of washed river gravel of rounded form that passed through a mesh of about one-eighth inch and cement having a slump of the order of one inch to coat a vertical surface of a swimming pool. The mix is very rich in cement, for example of the order of 1:1 by volume.

U.S. Patent No. 5,447,752 discloses a surface coating composition of cement, sand, a polymer binder and water for applying to a pre-existing cementitious surface. A plastic template is laid on the pre-existing surface and the coating composition is applied and the template removed. Texturizing rollers can be used to provide a more realistic finish.

U.S. Patent No. 5,252,636 discloses a dry mixture for epoxy cement concrete for the preparation of mortars and concretes. The composition comprises a reactive resin and hardener therefor. Disclosed examples of reactive resin are the well-known type of polymeric substance cured by reaction with a hardener commercially available as the so-called two component resin such as polyurethane and epoxy resins. The corresponding hardener is a compound containing isocyanate respective amino groups, depending on the resin used. In addition to the reactive resin and hardener

therefor, the mixture can also comprises a hydraulic binder, silica fume, fly ash, aggregate which is normally sand, gravel, slag, glass and plastic fibres, and admixtures which include superplasticizer, and other additives.

Other decorative aggregate-containing surfaces are disclosed in U.S. Patent Nos. 2,296,453; 3,608,038; 4,049,874; 4,134,956; and 4,205,040.

Various cementitious compositions are known that contain one or more of the following portland cement, fly ash, silica fume or quartz materials. The following compositions are used for various purposes not associated with, or related to, forming decorative aggregate-containing surfaces. For example, U.S. Patent No. 4,111,711 discloses civil engineering and refractory cement compositions which consist of three main ingredients each of which may be selected from three varying lists of materials. The first ingredient can be a silico aluminous cement. The second ingredient has a particle size between 100Å -0.1 microns and can be silica. The third ingredient, has a particle size between 1 micron to 100 microns, and is an inert filler, insensitive to hydration. The third ingredient can be quartzite or pure quartzitic sands. Fly ash is not mentioned. In all cases it appears that the cement must under go a complete dehydration at a temperature from 800°C to 1000°C before it is useful as a ingredient in concrete.

U.S. Patent No. 4,210,457 discloses a structural concrete comprising Portland cement, fly ash and sand. In several comparative tests ground quartz was used in place of the fly ash.

There is no disclosure of using both ground quartz and fly ash in the same compositions.

U.S. Patent No. 4,501,830 discloses a lightweight cement product formed from a mixture comprising cement, condensed silica fume, fly ash cenospheres, finely divided crystalline silica particles, epoxy emulsion, curing agent, accelerator and water. The cementitious compositions harden in less than one hour. The mixes, after pouring into a mold, were cured in a steam box at 60°C (140°F) for one day and produced products having compressive strengths of over 6000 psi.

U.S. Patent No. 4,506,025 discloses a refractory composition formulated from quartzite, vitreous and fused silica, portland cement, a water-reducing agent and wollastonite powder. The composition requires drying at 250°F - 500°F.

U.S. Patent No. 5,114,617 discloses a high strength concrete useful in prestressed products. The composition comprises cement, expanded perlite, microsilica or fly ash, a fine aggregate, and an optional coarse aggregate. Disclosed examples of the aggregate are sand, gravel, slag, expanded shale (Haydite) and expanded clay. Expanded oil shale (Haydite) is used as the coarse aggregate in Example I. Superplasticizers are also used.

U.S. Patent No. 5,346,548 discloses a blend of rice hull ash ("RHA") and cement. Concrete and mortar products made from the blends are said to have high strength and low permeability to water and chloride ions. Early strength in concrete compositions is provided by the addition of fly ash. The patent discloses cement

products made from formulations containing siliceous ash from crop residue, namely, RHA. The formulations require both a fine and a coarse aggregate. The coarse aggregate is crushed limestone and the fine aggregate is quartzitic sand. Other fine and coarse aggregates as would customarily be employed in mortar and concrete compositions are said to be equally suited in the present invention. The compressive strength of the RHA formulations are compared to reference concretes made without the RHA. No mention is made of silica fume.

U.S. Patent No. 5,383,967 discloses a blended cement comprising gypsum, portland cement clinker, and a comminuted mineralogic silica for example feldspars, zeolites, diatomaceous earths, clinoptilites, mordenites, chabozites, opaline silica, novaculites, vitreous volcanic rocks and high silica rocks having at least 50% by weight silica. One of the feldspars mentioned is feldspathic quartzite. The inclusion of silica fume appears to be discourage and fly ash is not mentioned.

U.S. Patent No. 6,251,178 discloses a hydraulic cementitious composition having portland cement, fly ash, lithium carbonate to reduce alkali silica reactivity, and optional metakaolin. The composition is said to be useful for construction of concrete article such as roadways. No mention is made of quartzite or silica fume.

U.S. Patent No. 6,332,920 discloses a slag for cementing an oil well. The cement slag comprises a hydraulic binder composition comprising Portland cement, microsilica of granulometry in the

range of 0.1 to 0.50 micrometers, medium particles of granulometry in the range of 0.5 to 200 micrometers, water-soluble superplasticizer. Disclosed examples of the medium particles are balls of plastic materials, silicas, clay, glass balls, metallic salts, barite, haematite, ilmenite, siliceous particles, silica sand, **crushed quartz**. Fly ash is not mentioned.

The above described compositions and methods either:

1. Do not form monolithic structures, or
2. Disperse the relatively expensive decorative aggregate throughout the entire structure thereby increasing cost, or
3. Require labor intensive hand seeding or broadcasting of the decorative aggregate, or
4. Require a labor intensive and hence costly grinding step, or
5. Employs a relative stiff and sticky surface coating having a slump of the order of one inch that would be very difficult if not impossible to work by leveling, bullfloating, troweling and sponging to produce a smooth decorative aggregate-containing surface durable and effective for traffic.
6. Are not shown to be effective for binding or securing exposed decorative aggregate in a decorative aggregate-containing surface which is suitable for traffic.

A decorative aggregate-containing cementitious matrix composition and installment method without any of these disadvantages would reduce the cost and/or increase the durability of the structure and/or produce monolithic structures.

SUMMARY OF THE INVENTION

This invention is directed towards compositions and processes for producing durable and attractive decorative aggregate-containing cementitious surfaces that are an integral part of structures, especially monolithic structures.

This invention is also directed towards processes that:

1. Can produce such surfaces at a much lower cost by not requiring hand seeding or broadcasting of decorative aggregate over the top of such surfaces during their manufacture.
2. Do not required decorative aggregate throughout the entire monolithic structure.
3. Do not require grinding the cured surfaces in order to produce an attractive and/or durable decorative aggregate-containing surface with exposed decorative aggregate.

This invention can be used on monolithic structures having any strength desired and suitable for usage ranging from light pedestrian traffic on home patios to heavy vehicular traffic. This invention is mainly intended for new monolithic structures in compliance with the least stringent specifications to the most stringent specifications depending only on the required duty that such monolithic structures are to serve. For example, this invention can produce monolithic structures having strength ratings of 2200 psi, 3000 psi, 4000 psi or higher if desired. Unless otherwise specified all psi strength rating referred herein are concrete compressive strengths at 28 days. The compositions of this invention can also be applied to existing cementitious bases.

Accordingly, in one embodiment of this invention there is provided by the principles of this invention a process for producing a monolithic architectural cementitious structure having a decorative aggregate-containing cementitious surface comprising forming a freshly poured cementitious base. The cementitious base does not contain any decorative aggregate. With reference to FIG. 1, a compacted subgrade material 20 is preferably first laid on a rough graded site 21. Then reinforcing bar or rebar, or wire mesh 22 is set to reinforce the ultimately formed monolithic structure. Next a cementitious base 23 is produced and laid from suitable formulation having the strength properties required. Usually the decorative aggregate-containing cementitious portion of such structure is between 2% and 17% of the total thickness of monolithic architectural cementitious structure while the cementitious base is between 98% and 83% of said total thickness. In one embodiment, the freshly poured cementitious base 23 has a thickness of at least about 3 inches.

By the term "decorative aggregate" as used herein is meant aggregate that is used to produce an attractive or architectural surface. The term "decorative aggregate" as used herein is not meant to include any aggregate used for merely adding strength to the monolithic structure without also enhancing the beauty of the surface. For example, No. 4 aggregate, which is used in many concrete mixes for strength, is not a "decorative aggregate" as that term is used herein. The appearance of decorative aggregate is not the same as the appearance of the aggregate in the

cementitious base. Thus the aggregate used for adding strength to the cementitious base not the same as the decorative aggregate used for producing the attractive surfaces of this invention.

Since the decorative aggregate is relatively expensive material there is substantial cost savings in this process since the cementitious base does not contain the relatively expensive decorative aggregate. Furthermore, since the formulation of the decorative aggregate-containing cementitious slurry is relatively more expensive per unit volume than the formulation of the cementitious base per unit volume, the cost of producing the monolithic architectural cementitious structures with the decorative aggregate-containing surfaces is reduced when thickness of the decorative aggregate-containing cementitious layer is reduced. However, said thickness must be effective for securing and locking in the exposed decorative aggregate.

With reference to FIG. 2, this invention further comprises preparing a decorative aggregate-containing cementitious slurry 24 having at least decorative aggregate 26 and cementitious matrix composition 28 (also referred to herein as the decorative cementitious matrix blend) operable for forming a monolithic structure when applied to the freshly poured cementitious base and simultaneously cured therewith. In one embodiment of this invention, the cementitious matrix composition 28 comprises water, silica sand and cement. In another embodiment of this invention the silica sands are quartzitic silica also referred to quartzite.

Quartzite is sandstone that has been metamorphosed. Unlike sandstone, quartzite breaks through, not around, the quartz grains, producing a smooth surface instead of a rough and granular one. The color of quartzites ranges from snowy white, whitish, pink, reddish or gray. The term "quartzite implies not only a high degree of hardening or induration or "welding," but also a high content of quartz. Most quartzites contain 90% or more quartz, and some 99% quartz. Crushed quartzite is mostly a mosaic of small, irregular shaped crystalline fragments with interlocking margins.

In one embodiment of this invention the quartzite is blended quartzitic silica. Quartzite and blended quartzitic silica are available in several colors including light or white tones and darker colors. When the decorative cementitious matrix blend is not required to be white or light color in tone, the cement is Type V Portland cement or equivalent cement having low permeability. The low permeability is desirable because it is more resistant to sulfates in the soil, salty sea breezes, and other concrete-detrimental salts.

However, when the decorative cementitious matrix blend is required to be white or light color in tone, a white Portland cement is used since Type V Portland cement frequently has a darker appearance. To maintain the light color of the decorative cementitious matrix blend when using white Portland cements, any fly ash present in the formulation should be replaced by an additional amount or percent of white Portland cement. As stated at page 17 of Kosmatka and Panarese, "Design and Control Of

Concrete Mixtures", 13th Edition, Portland Cement Association, 1994, 4th printing, white Portland cement is a true Portland cement that differs from gray cement chiefly in color. It is made to conform to the specifications of ASTM C150, usually Type I or Type III, but the manufacturing process is controlled so that the finished product will be white. White Portland cement is made from selected raw materials containing negligible amounts of iron and magnesium oxides, i.e. the substances that give cement its gray color; see **TABLE** 1. Its use is recommended whenever white or colored concrete is desired. Usually, white Portland cement is equivalent in strength to Type I or Type III Portland cement.

Chemical and compound composition and fineness of some typical Portland cements can be found at page 21 of the above-mentioned "Design and Control Of Concrete Mixtures" publication and also in Kirk and Othmer, eds., "Cement," Encyclopedia of Chemical Technology, 3rd ed., vol. 5, John Wiley & Sons, Inc., New York, 1979, pages 163-193, and which is also shown in TABLE 1 for Portland cement Types I, III and white. Variations in the this data will occur from one cement source to another, however, such variations are still considered to fall within the specification of ASTM C150, which is hereby entirely incorporated herein by reference. These references may be consulted for more in-depth explanation of the effect of such parameters on concrete.

In one embodiment the cementitious matrix composition comprises silica fume for improving strength and securing the decorate aggregate. Condensed silica fume is a by-product from

silicon and ferrosilicon industries, where these metals are produced in submerged electric arc furnaces. The fume from these processes forms minute, glassy, spherical particles referred to as microsilica or silica fume that is considered a waste product of limited value. Microsilica is an extremely fine particulate, with average diameters 100 times finer than cement particles and is almost pure silicon dioxide or SiO_2. Most condensed silica fume has an average size of about 0.15 micrometers, while a typical Portland cement has an average particle size of 15 micrometers.

Since silica fume speeds up the rate of cure, effective retardants can be added, if needed, to allow more time for the resultant slurry to be worked. For example a small amount of fly ash Class C is added as a retardant where the decorative aggregate is 1/4 inch or larger and where the resulting decorative surface is not required to be white or light color in tone. As disclosed by ASTM designation C618-01, published September 2001 and in U.S. Patent Nos. 4,992,102 and 5,266,111 and 5.520,730, Class C fly ash is normally produced from lignite or subbituminous coal. This class of fly ash, in addition to having pozzolanic properties also has some cementitious properties. Some Class C fly ash may contain lime contents higher than 10%. Class C and F fly ash is characterized by American Society of Testing Materials (ASTM) Standard C618 that sets forth the following chemical (oxide basis)

and physical requirements:

C	F	Class
50%	70%	Minimum $SiO_2 + Al_2O_3 + Fe_2O_3$
5%	5%	Maximum sulfur trioxide (SO_3)
3%	3%	Maximum moisture content
6%	6%	Maximum loss on ignition
34%	34%	Maximum amount retained when wet-sieved on 35 microns (No. 325) sieve.

Class F fly ash normally produced from burning anthracite or bituminous coal has pozzolanic properties. The reference to "pozzolanic properties" refers to the capability of certain mixtures that are not in themselves cementitious of undergoing a cementitious reaction when mixed with lime in the presence of water. Class C fly ash possesses direct cementitious properties as well as pozzolanic properties. Pat. Nos. 4,992,102 and 5,266,111 and 5,520,730, disclose how to produce synthetic Class C fly ash from Class F fly ash and cement kiln dust (CKD) and are hereby entirely incorporated herein by reference. Synthetic Class C fly ash and other equivalent materials thereof can be used in this invention. Accordingly, by the expression "Class C-like" fly ash as used herein is meant to include Class C fly ash, synthetic Class C fly ash and fly ash that has both pozzolanic properties and cementitious properties equivalent to Class C fly ash. Class F fly ash without CKD can also be used in place of the above-mentioned synthetic Class C fly ash, however it would not be as effective.

Superplasticizers can be also be added to the decorative cementitious matrix blend to make a flowing concrete and/or to reduce water content to gain higher early strengths, for example polymer containing WRDA ® -19 brand superplasticizer and chemical dispersants containing DARACEM ® -100 brand superplasticizer of W. R. Grace & Co.

In one embodiment, the process further comprising leaving a rough, unsmoothed and wet surface 30 on the freshly poured cementitious base, and pouring the decorative aggregate-containing cementitious slurry 24 on the rough, unsmoothed and wet surface 30.

Non-limiting examples of decorative aggregate 26 are natural hard materials, synthetic hard materials, and mixtures thereof that form decorative aggregate-containing cementitious surfaces. Other non-limiting examples are decorative aggregate selected from the group consisting of ceramic, ceramic chips, marble, marble chips, granite, granite chips, sea shells, sea shells chips, sea crustacean remains, fragments of sea crustacean remains, glass, glass chips, natural aggregates selected for their color, natural aggregates selected for their texture, natural aggregates selected for their attractiveness and strength, and mixtures thereof.

In one embodiment of this invention, the decorative aggregate has a size between about 1/32 inch and about 1/2 inch. In another embodiment, the decorative aggregate has a size between about 1/32 inch and about 3/8 inch. Sizes of the decorative aggregate when referred herein mean the mean diameter of the decorative aggregate unless otherwise specified.

In one embodiment, the process further comprising removing detrimental material, including dirt and grit, from the decorative aggregate before preparing the decorative aggregate-containing cementitious slurry.

The process further comprises pouring an amount of the decorative aggregate-containing cementitious slurry 24 on the freshly poured cementitious base within a period of time after forming the freshly poured cementitious base, effective for forming a monolithic structure, when simultaneously cured with the freshly poured cementitious base. The amount of the decorative aggregate-containing cementitious slurry 24 must be sufficient to produce a decorative aggregate-containing cementitious layer having a thickness 31 operable, when cured, for permanently securing the decorative aggregate therein. Furthermore, at least a portion of the decorative aggregate forms a portion of the exposed surface of the decorative aggregate-containing cementitious layer.

In one embodiment, the period of time for pouring the decorative aggregate-containing cementitious slurry on the freshly poured cementitious base between about one minute and no more than about 3 hours from the time of completing the pouring of the freshly poured cementitious base. In another embodiment, the period of time for pouring the decorative aggregate-containing cementitious slurry on the freshly poured cementitious base is immediately after, or as soon as possible after, completing the pouring of the freshly poured cementitious base.

The one embodiment, the process further comprises adding and mixing a colorant in the decorative aggregate-containing cementitious slurry before pouring the slurry on the freshly poured cementitious base.

The process further comprises simultaneously curing (1) the decorative aggregate-containing cementitious slurry poured on the freshly poured cementitious base, with (2) the freshly poured cementitious base, for a period of time effective for producing a monolithic architectural cementitious structure **32** having a decorative aggregate-containing cementitious surface 34, as represented in **FIG. 3**, in which the boundary **36** seen in FIG. 2, between the earlier poured cementitious base 23 and the decorative aggregate-containing cementitious slurry 24 has vanished due to the cementitious reaction resulting from the curing process thereby producing a monolithic structure.

The period of time for a 75% cure of the decorative aggregate-containing cementitious slurry and the freshly poured cementitious base is about 7 days under normal conditions.

In one embodiment, in about 30 minutes after pouring the decorative aggregate-containing cementitious slurry, the process further comprises leveling the decorative aggregate-containing cementitious surface. In another embodiment, in about 30 minutes after leveling the decorative aggregate-containing cementitious surface, the process further comprises bullfloating the decorative aggregate-containing cementitious surface and forming a smoothed surface. In still another embodiment, in about 60 minutes after

bullfloating the decorative aggregate-containing cementitious surface and forming the smoothed surface, the process further comprises troweling and sponging the decorative aggregate-containing cementitious surface to further enhancing the appearance thereof.

In a further embodiment, the process comprises, after about 7 days of curing the decorative aggregate-containing cementitious slurry with the freshly poured cementitious base, washing the decorative aggregate-containing cementitious surface with a dilute acid to brighten exposed decorative aggregate.

In another embodiment, after washing the decorative aggregate-containing cementitious surface with a dilute acid to brighten exposed decorative aggregate, the process further comprises testing the surface to determine if the dilute acid has been neutralized, and after the testing shows that the surface has been neutralized, sealing the surface with a sealant effective for protecting the surface. The dilute acid will become neutralized in about 2 to about 8 days after the dilute acid washing.

In one embodiment, the thickness 31 of the decorative aggregate-containing cementitious layer is at least about 1/16 inch. In another embodiment, the monolithic architectural cementitious structure has a thickness 38 of at least about 3 5/8 inches, i.e. nominally 4 inches.

There is also provided by the principles of this invention decorative cementitious matrix blends comprising blended quartzitic silica, Portland cement, and silica fume, which when mixed with an

effective amount of water, followed by mixing with a predetermined amount of decorative aggregate, can be used to form the decorative aggregate-containing surfaces of this invention. In one embodiment, the decorative cementitious matrix blend also comprises a small amount Class C-like fly ash as a curing retardant. Minor amounts of other accelerants, retardants, and/or hardeners can, of course, be used if desired.

In one embodiment, the effective amount of water that is added to the decorative cementitious matrix blend and of decorative aggregate forms a slurry having sufficient fluidity that the slurry can be worked through the last troweling step of producing the smooth decorative aggregate-containing surface. However, said amount of water shall be limited so that it does not produce surface shrinkage cracking the first day of curing, nor premature surface wearing thereafter.

In one embodiment of this invention, the effective amount of water that is added to the decorative cementitious matrix blend and of decorative aggregate is effective for forming a slurry having a slump of at least about 2 inches, and preferably at least about 3 inches.

In another embodiment of this invention, the effective amount of water that is added to the decorative cementitious matrix blend and of decorative aggregate is effective for forming a slurry having a slump of no greater than about 6 inches, and preferably no greater than about 5 inches.

In still another embodiment, the effective amount of water that is added to the decorative cementitious matrix blend and of decorative aggregate forms a slurry having a slump between about 3 inches and 5 inches.

In one embodiment, the dry components comprise about 60 parts of decorative cementitious matrix blend and about 40 parts of decorative aggregate, which is then slurried with water to produce the decorative aggregate-containing cementitious slurry.

In one embodiment, the decorative cementitious matrix blend contains between about 20% and about 35% of Portland cement or equivalent cement thereto, preferably between about 22% and about 33%, and especially preferably between about 25% and about 32%.

In one embodiment, the decorative cementitious matrix blend contains between about 50% and about 79% blended quartzitic silica or an equivalent silica thereto, preferably between about 55% and 75%, and especially preferably between about 60% and 70%.

In another embodiment of this invention, the blended quartzitic silica, when characterized using Standard Sieve Sizes 4, 8, 16, 30, 50 and 100, has a particle size smaller than Standard Sieve Size 4, between about 0% and about 6% smaller than Standard Sieve Size 4 and larger than Standard Sieve Size 8, between about 7% and about 18% smaller than Standard Sieve Size 8 and larger than Standard Sieve Size 16, between about 16% and about 44% smaller than Standard Sieve Size 16 and larger than Size 30, between about 24% and about 42% smaller than Standard Sieve Size 30 and larger than Standard Sieve Size 50, between about 6% and about 18% smaller

than Standard Sieve Size 50 and larger than Size 100, and no more than about 7% smaller than Standard Sieve size 200.

In still another embodiment of this invention, the blended quartzitic silica, when characterized using Standard Sieve Sizes 4, 8, 16, 30, 50 and 100, has a fineness modulus between about 2.1 and about 3.1.

In yet another embodiment, the blended quartzitic silica, when prepared from Sand Size Nos. 16, 20, 30 and 60, is about 25% Sand Size No. 16, about 37% Sand Size No. 20, about 25% Sand Size No. 30, and about 13% Sand Size No. 60. The screen analysis of these Sand Size Nos. is shown in **TABLE 1A**. The screen size of such quartzitic silica blend is shown in **TABLE 1B**. In this example the quartzitic silica blend has a particle size distribution of about 100% passing through Standard Sieve Size 8, about 93% passing through Standard Sieve Size 16, about 49% passing through Standard Sieve Size 30, about 7% passing through Standard Sieve Size 50, about 1% passing through Standard Sieve Size 100, and a fineness modulus of 2.5.

In another embodiment, the decorative cementitious matrix blend contains silica fume up to about 5%, and preferably up to about 4%, and especially preferably up to about 3.5% as a strengthening and binding agent.

In still another embodiment, the decorative cementitious matrix blend contains silica fume up to about 5%, and preferably between about 0.1% and about 4%, and especially preferably between about 1.5% and about 3.5% as a strengthening and binding agent.

In one embodiment that include decorative aggregates larger that about 1/4 inch and that are not used to form white or light colored surfaces, the decorative cementitious matrix blend contains Class C-like fly ash up to about 8% as a retardant or water reducer. In another embodiment, the decorative cementitious matrix blend contains Class C-like fly ash up to about 7%. In still another embodiment, the decorative cementitious matrix blend contains Class C-like fly ash of at least about 5%. In yet another embodiment, the decorative cementitious matrix blend contains Class C-like fly ash between about 5% and about 7%.

In one embodiment, the ratio of cement to blended quartzitic silica is between about 10/40 (25%) and about 25/40 (63%), preferably between about 12/40 (30%) and about 22/40 (55%), and especially preferably between about 15/40 (37%) and about 20/40 (50%).

In one embodiment, the ratio of silica fume to blended quartzitic silica is up to about 4/40 (10%), preferably between about 0.5/40 (1%) and about 2/40 (5%), and especially preferably between about 1/40 (2.5%) and about 2/40 (5%).

In one embodiment, the ratio of decorative aggregate to decorative cementitious matrix blend is between about 20/60 (33%) and about 50/60 (83%), preferably between about 35/60 (58%) and about 45/60 (75%), and especially preferably about 40/60 (67%).

In one embodiment, the ratio of cement to decorative aggregate is between about 10/40 (25%) and about 30/40 (75%), preferably

between about 12/40 (30%) and about 25/40 (63%), and especially preferably between about 15/40 (37%) and about 20/40 (50%).

In one embodiment, the ratio of silica fume to decorative aggregate is up to about 4/40 (10%), preferably between about 1/100 (1%) and about 3/40 (7.5%), and especially preferably between about 1/40 (2.5%) and about 2/40 (5%).

In one embodiment, the size of the decorative aggregate is no greater about 1/2 inch, preferably no greater than about 3/8 inch, and especially preferably no greater than about 1/4 inch.

In another embodiment, the size of the decorative aggregate is between about 1/32 inch and about 1/2 inch, preferably between about 1/32 inch and about 3/8 inch, and especially preferably between about 1/32 inch and about 1/4 inch.

Because the decorative aggregate-containing surfaces prepared according to the principles of this invention require that the installer should work relatively fast to produce such surfaces in order to prevent the premature of curing of the decorative aggregate-containing cementitious slurry. This can be achieved by sequentially installing one small areas at a time before moving on to the next small area. To enable this to be easily and economically accomplished, in one embodiment of this invention the dry blended cementitious matrix composition is packaged in convenient sizes. In one embodiment of this invention the packaged dry blended cementitious matrix composition is contained in bags of between about 20 lbs. and about 120 lbs. In another embodiment, the bags of packaged dry blended cementitious matrix composition

are about 60 lbs., which conveniently allows the one 60 lb. bag of packaged dry blended cementitious matrix composition, 40 lbs. of decorative aggregate and an effective amount of water to be mixed in a small batch mixer at the job site and the resulting decorative aggregate-containing cementitious slurry to be quickly poured onto the cementitious base or other base surface, then leveled and trowelled. In one embodiment, for a thickness of 3/8 inch, one 60 lb. bag when slurried with 40 lbs. of decorative aggregate will cover about 200 square feet.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is an elevational and cross-sectional view of cementitious matrix composition poured on a prepared subgrade material.

FIG. 2 is an elevational and cross-sectional view of a decorative aggregate-containing cementitious slurry poured on top of the rough, unsmoothed and wet surface of the cementitious matrix composition of FIG. 1.

FIG. 3 is an elevational and cross-sectional view of a monolithic architectural cementitious structure having a decorative aggregate-containing cementitious surface resulting from the curing of the formation of FIG. 3.

FIG. 4 is flow diagram of a process for producing a monolithic architectural cementitious structure having a decorative aggregate-containing cementitious surface beginning with preparing a rough graded site to sealing the produced surface.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

Referring to FIG. 4, a flow diagram of the preferred processing steps of this invention for producing a monolithic architectural cementitious structure suitable for continuous traffic begins with rough grading an identified site in step **40** to a first predetermined elevation by grading the site to ±0.1 ft of specification. Thereafter, if required, installing on the rough graded site a subgrade material 20, in step **42**, selected from the group consisting of sand, and crushed aggregate and mixtures thereof, or other subgrade material, and compacting the subgrade material, in step **44**, with water **43** sprinkled on the subgrade material laid in step 42.

Next, in step **45**, pouring on top of the subgrade material a cementitious base 23 to a specified minimum thickness and to a second predetermined elevation, and screeding or rodding the freshly poured cementitious base, in step **46**. Then forming and leaving a freshly poured cementitious base having a rough, unsmoothed and wet surface 30, in step **48**, for achieving a monolithic cementitious reaction with a subsequently applied and simultaneously cured decorative aggregate-containing cementitious layer.

Screed boards are the boards used to form the boundary of the area to be poured with the cementitious composition. The top edge of the screed boards are set at the elevation desired or specified. Screeding or rodding is a term in the industry meaning dragging or

pulling a wooden board or rod, usually a long 2 inch x 4 inch board, or similarly-shaped steel member, laid over top edges of the screed boards to level the surface of a freshly poured cementitious layer. Screeding or rodding is performed in step 46 as well as step 75 described later. In step 46, however, screeding is deliberately stopped before achieving a smooth surface.

While, or preferably before, the above-described steps 40 to 48 are being carried out, a decorative aggregate 26 introduced at 50 is washed with water 52, in step 54, thereby producing a supply of clean decorative aggregate in step 56 that is free of detrimental material. Also, while the above-described steps 40 to 48 are being carried out, a pourable, or flowable, or pumpable cementitious matrix composition 28 is simultaneously prepared in step 60 by mixing silica sand 62 and water 64 in a mixer followed by adding and mixing cement 66 in the mixer. The silica sand used is the quartzitic silica blend of this invention. If desired, a colorant 68 is then added and mixed in the mixer to form the cementitious matrix composition. An example of a colorant is iron oxide.

The cleaned decorative aggregate produced in step 56 is then added and mixed with the cementitious matrix composition in step 70, to produce a pourable, or flowable, or pumpable decorative aggregate-containing cementitious slurry. Next, in step 72, the decorative aggregate-containing cementitious slurry is then applied to, or poured on, the rough, unsmoothed and wet surface of the freshly poured cementitious base produced and laid in step 48.

The labor-intensive step of hand seeding or broadcasting the decorative aggregate is not required in this process thereby greatly reducing the cost of construction and speeding installation of the structure.

To permanently secure the decorative aggregate in the subsequently cured monolithic structure the thickness of the decorative aggregate-containing cementitious layer must be sufficient that upon curing it will secure or lock in the largest size of the decorative aggregate employed. For example, it is recommended that if the decorative aggregate has a maximum size of 1/2 inch, that the decorative aggregate-containing cementitious layer be about 5/8 inch thick to secure or lock in the decorative aggregate while permitting at least a portion of the decorative aggregate to be exposed at the surface thereby forming, in step 74, a decorative aggregate-containing cementitious surface 34 having a portion of the decorative aggregate exposed.

Similarly, if the decorative aggregate has a maximum size of 3/8 inch, then the decorative aggregate-containing cementitious layer should be about 1/2 inch thick.

If the decorative aggregate has a maximum size of 1/4 inch, then the decorative aggregate-containing cementitious layer should be about 3/8 inch thick.

If the decorative aggregate has a maximum size of 1/8 inch, then the decorative aggregate-containing cementitious layer should be about 3/16 inch thick.

If the decorative aggregate has a maximum size of 1/16 inch, then the decorative aggregate-containing cementitious layer should be about 1/8 inch thick.

If the decorative aggregate has a maximum size of 1/32 inch, then the decorative aggregate-containing cementitious layer should be about 1/16 inch thick.

To further enhance the appearance of the decorative aggregate-containing cementitious layer, the poured decorative aggregate-containing cementitious slurry is within about 30 minutes after pouring leveled in step 75, then within about 30 minutes after leveling bullfloated in step 76, then within 60 minutes after bullfloating troweled in step 77, and then immediately sponged in step 78. In other words, these steps are performed shortly after pouring and laying the decorative aggregate-containing cementitious slurry so that most of the monolithic forming cementitious reaction occurs after step 78, thereby insuring that no cold joint is formed between the freshly poured cementitious base and the decorative aggregate-containing cementitious slurry.

Leveling, carried out in step 75, is performed by screeding or rodding. However, as opposed to step 46, screeding in step 75 continues sufficiently to level and preliminarily smooth the top surface.

Bullfloating, carried out in step 76, is a term used in the industry meaning dragging a wooden board or similarly-shaped steel member, usually attached to a long pole, at an acute angle over the

surface of an uncured cementitious layer to further smooth the surface thereof.

Troweling, carried out in step 77, is a term used in the industry meaning the operator, using knee boards if necessary, works his way over the uncured surface from one small area to another, using hand held trowels and smoothing the surface as he moves.

Sponging, carried out in step 78, is a term used in the industry meaning removing the excess cement film after troweling and is usually performed by the operator immediately following troweling before moving on his knee boards to the next small area to be troweled.

After completing the sponging carried out in step 78, the entire cementitious formation is allowed to cure, i.e. allowing the monolithic cementitious reaction to proceed undisturbed and form a harden surface. Curing is allowed to occur for about 7 days in step 80 while keeping the entire surface damp, before proceeding with subsequent surface treatments.

After the 7 day curing in step 80, the harden surface is brushed and lightly washed with a dilute acid to remove the laitance covering the exposed portion of the decorative aggregate in step 82. "Laitance" is a term used in the industry to mean the thin cementitious surface film left after curing. An effective dilute acid for washing is a mixture of one part by volume muriatic acid to ten parts by volume water. Muriatic is usually sold with a hydrochloric acid strength of from about 35% to about 38%.

After acid washing, the decorative aggregate-containing cementitious surface of the monolithic structure is allowed to become neutralized in 83. Neutralization can be determined by testing the surface with litmus paper or other means. The neutralized decorative aggregate-containing cementitious surface is then sealed with an effective sealant, as indicated in step 84. Acrylic based sealants are examples of effective sealants.

As mentioned earlier, compositions of this invention can also be applied to existing cementitious bases or other suitable existing hard bases. For example, with existing bases rather than steps 40 to 48 and 72, the existing base can be prepared by roughening, cleaning and/or chemically treating sufficiently to enable the decorative aggregate-containing cementitious slurry prepared in step 70 to be applied directly to and cured on, the existing base. Although a cold joint is formed, with some existing bases the bond is adequate to produce an attractive and durable surface at considerable cost savings. However, such decorative aggregate-containing cementitious surfaces should not be expected be as durable as when the decorative aggregate-containing cementitious slurry is poured on a freshly poured cementitious base as discussed earlier and illustrated in FIG. 2. Nevertheless, because of the saving in time and cost, such surface applications will be beneficial to the industry particularly where heavy vehicular traffic is not encountered.

If the cementitious base poured in step 45 is at least about 3 to 3 1/2 inches thick, and the decorative aggregate-containing

cementitious layer is at least about 1/32 to 5/8 inch thick depending on the maximum size of the decorative aggregate, the monolithic structure produced upon curing will be sufficient to support heavy pedestrian traffic, and provide attractive walkways for amusement parks, sidewalks, patios, amusement parks streets, and hotel entrances and the like having long lasting and superior durability. For city streets the total thickness of the monolithic structure should meet or exceed specification, which can require between 6 and 8 inch thickness.

The cementitious materials when cured have known strength ratings. Specifications for the cementitious materials usually require that they have a certain minimum strength when cured to meet the requirement established by governmental bodies. In this invention, the freshly poured cementitious base and the decorative aggregate-containing cementitious slurry when cured each have a strength rating. In one embodiment of this invention, the strength rating of the freshly poured cementitious base when cured, and the strength rating of the decorative aggregate-containing cementitious slurry when cured, are about the same so that one of these materials will not deteriorate before the other. For example, if one material has a rating of 2200 psi, the other one should also have a rating of 2200 psi. Cementitious materials frequently have rating of 2200 psi, 3000 psi, 4000 psi or higher depending on the usage that such cementitious materials are going to encounter.

Example 1

A cementitious base is poured with an amount of mix sufficient to produce a 3 to 5 inch pour thickness. The amount of water preferably is sufficient to produce about a 3 to 5 inch slump test. For example, the following formulation produces a satisfactory cementitious base:

%	Ingredient
16	Riverside Type V Portland (ASTM C150)
26	No. 4 aggregate
48	Washed concrete sand
10	water
100	

Primary aggregate gradation of No. 4 aggregate is as follows:

% Passing	U.S. Standard Sieve
100	1/2 inch
96	3/8 inch
14	#4
4	#8
1	#16
5.85	Fine Material (ASTM C125)

A decorative aggregate-containing cementitious slurry is then immediately poured on the freshly poured cementitious base. The amount of the slurry is sufficient to produce a poured layer having a thickness effective for securing and locking in the decorative aggregate. The workability of the decorative aggregate-containing

cementitious slurry must be effective for allowing operations through the final troweling, step 77 of FIG. 4.

The cementitious base and decorative aggregate-containing cementitious slurries of this invention produce monolithic structures having a design strength of 3000 psi or higher at 28 days.

The No. 4 aggregate adds strength to the cementitious base. No. 4 aggregate is much less costly than most all of the decorative aggregates of interests. No. 4 aggregate, or any other conventional aggregate used in conventional cement mixes merely for strength, does not produce the attractive or architectural surfaces of this invention, and therefore is not meant to be included in the term "decorative aggregate" as used and claimed herein.

Example 2

Non-limiting examples of decorative cementitious matrix blends of this invention are shown in **TABLE 2**. Decorative cementitious matrix blends A, B, D and E are darker than lighter blends G, H, J and K that are formulated to produce a whitish to light beige appearance. The fly ash in blends A and B retards the curing rate and allows more time to work with forming the decorative aggregate-containing surface. Silica fume is used to improve the decorative-aggregate binding strength of the decorative aggregate-containing surface. Other decorative cementitious matrix blends can, of course, be used in the process of this invention.

By the transitional term "consisting essentially of" is meant to exclude:

1. non-cementitious chemical compositions, other than those compositions and materials stated, which materially affect the ultimate binding characteristics of the decorative aggregate-containing surface to the exposed decorative aggregate, or
2. additives, other than those compositions and materials stated, which materially affect the ultimate binding characteristics of decorative aggregate-containing slurry made from the dry blended cementitious matrix composition to a freshly poured cementitious base, or
3. raw materials, other than those compositions and materials stated, used to produced manufactured portland cement, whether used as a cementitious material or as a filler.

Examples of 1 and 2. are epoxy compositions, reactive resins and hardeners therefor.

Examples of 3. are limestone, gypsum, cement clinkers, fillers, alkali waste, calcite, CKD, cement rock, chalk, clay, fuller's earth, limestone, marl, shale, slag, blast furnace flue dust, iron ore,mill scale, ore washings, pyrite cinders, calcium silicate, loess, siliceous ash from crop residue, RHA, aluminum-ore refuse, bauxite, calcium sulfate, gypsum.

By the term "elevated temperature" is meant heating to above ambient or outside temperature to effect curing of the decorative aggregate-containing cementitious slurry.

While the preferred embodiments of the present invention have been described, various changes, adaptations and modifications may be made thereto without departing from the spirit of the invention and the scope of the appended claims. The present disclosure and embodiments of this invention described herein are for purposes of illustration and example and modifications and improvements may be made thereto without departing from the spirit of the invention or from the scope of the claims. The claims, therefore, are to be accorded a range of equivalents commensurate in scope with the advances made over the art.

TABLE 1

Type of Portland Cement	Chemical Composition (%)						Loss on Ignition (%)	Insoluble Residue (%)	Potential Compound Composition (%)[1]				Blaine Fineness (m^2/kg)
	SiO_2	Al_2O_3	Fe_2O_3	CaO	MgO	SO_3			C_3S	C_2S	C_3A	C_4AF	
I	20.9	5.2	2.3	64.4	2.8	2.9	1.0	0.2	55	19	10	7	370
III	21.3	5.1	2.3	64.9	3.0	3.1	0.8	0.2	56	19	10	7	540
V	25.0	3.4	2.8	64.4	1.9	1.6	0.9	0.2	38	43	4	9	380
White	24.5	5.9	0.6	65.0	1.1	1.8	0.9	0.2	33	46	14	2	490

C_3S = $3CaO \cdot SiO_2$ = Tricalcium silicate
C_2S = $2CaO \cdot SiO_2$ = Dicalcium silicate
C_3A = $3CaO \cdot Al_2O_3$ = Tricalcium aluminate
C_4AF = $4CaO \cdot Al_2O_3 \cdot Fe_2O_3$ = Tetracalcium aluminoferrite

[1]Potential Compound Composition refers to the maximum compound allowable by ASTM C150 calculations using the chemical composition of the cement. The actual compound may be less due to incomplete or altered chemical reactions. Reference Steven H. Kosmatka and William C. Panarese, "Design and Control of Concrete Mixtures," 13th Edition, Portland Cement Association, 1994, 4th printing, page 21.

TABLE 1A

US SIEVE SIZE	PARTICLE SIZE OF QUARTZITIC SILICA SAND SIZE NO.			
	16	20	30	60
	% RETAINED ON SIEVE			
4	0	0	0	0
8	0	0	0	0
16	27	1	0	0
30	63	58	27	<1
50	8	40	71	53
100	0	0	2	44
200	0	0	0	1
CHEMICAL ANALYSIS OF QUARTZITIC SILICA				
Fe_2O_3	0.47	0.31	0.29	0.38
Al_2O_3	10.00	9.22	8.43	10.30
SiO_2	81.1	82.9	84.4	81.1
K_2O	4.91	4.47	3.97	4.36
CaO	0.55	0.74	0.67	1.05
Na_2O	1.98	1.80	1.70	2.19
MgO	0.14	0.10	0.05	0.13
TiO_2	0.14	0.06	0.06	0.06
MnO	<0.01	<0.01	<0.01	<0.01
BaO	0.21	0,19	0.17	0.18
P_2O_5	<0.05	<0.05	<0.05	<0.05
S	<0.05	<0.05	<0.05	<0.05
Cl	<0.02	<0.02	<0.02	<0.02

TABLE 1B

US SIEVE SIZE	PARTICLE SIZE OF BLENDED QUARTZITIC SILICA		
	% RETAINED ON SIEVE	ACCUMULATIVE % LARGER	ACCUMULATIVE % SMALLER
4	0	0	100
8	0	0	100
16	7.12	7.12	93.88
30	44.09	51.21	48.79
50	41.44	92.65	7.35
100	6.35	99.00	1.00
200	0.13	99.13	0.87

CHEMICAL ANALYSIS OF BLENDED QUARTZITIC SILICA	
Fe_2O_3	0.34
Al_2O_3	9.36
SiO_2	82.59
K_2O	4.44
CaO	0.72
Na_2O	1.87
MgO	0.10
TiO_2	0.08
MnO	<0.01
BaO	0.19
P_2O_5	<0.05
S	<0.05
Cl	<0.02

TABLE 2

	Component in Parts by Weight							
Decorative Cementitious Matrix Blend	A	B	D	E	G	H	J	K
Blended Quartzitic Silica[1]	40	40	40	40	40	40	40	40
Portland Cement Type V	15	16	18	18	0	0	0	0
White Portland Cement	0	0	0	0	19	19	18	18
Silica Fume	1	1	2	2	1	1	2	2
Fly Ash C	4	3	0	0	0	0	0	0
Decorative Aggregate[2]	40	40	40	40	40	40	40	40
Size Range Minimum - Inches	3/8	1/4	1/32	1/8	3/8	1/4	1/32	1/8
Size Range Maximum - Inches	1/2	3/8	1/8	3/8	1/2	3/8	1/8	3/8
Water[3]								

[1]The blended quartzitic silica is beige in A, B, D and E and white in G, H, J and K with a Standard Sieve Size gradation of 25% No. 16, 37% No. 20, 25% No. 30 and 13% No. 60.

[2]In A, B and D the decorative aggregates are nonwhite; in Blend E the decorative aggregates are nonwhite small sea shells and/or other sea crustations; in Blends G, H and J the decorative aggregates are white quartz marble or other white decorative aggregates; and in Blend K the decorative aggregates are white small sea shells and/or other sea crustations.

[3]An amount of water with or without superplasticizer or water reducer, which when added to the combined Decorative Cementitious Blend and Decorative Aggregate, produces slurries with sufficient fluidity through final troweling.